ATLANTIC STATES WEATHER, INC.
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Meteorological Analysis for Severe Hail at 10 West Main Street, Ardmore Oklahoma, 73401 (August 16, 2020)

[Pendant Properties, LLC]

Prepared for:
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April 19, 2023

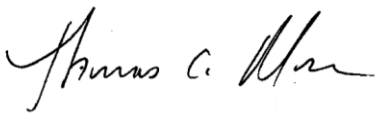
This report is subject to revisions based on new information and data if any becomes available.

ATLANTIC STATES WEATHER, INC. CORPORATE SEAL 2004 NORTH CAROLINA

This report is a meteorological analysis of weather conditions at 10 West Main Street, Ardmore Oklahoma, 73401, with a specific focus on the potential occurrence of severe hail on August 16, 2020.

The analysis, findings and opinions in this report are based on relevant weather and other data records available at the time the report was written, using commonly accepted meteorological best practices. This report has been prepared for use with this specific case only, and is subject to revision based on new information and data if any becomes available.

This report was prepared by Thomas C. ("TC") Moore, Certified Consulting Meteorologist. Mr. Moore has been a practicing meteorologist for over 32 years, and specializes in providing forensic meteorological services for a wide variety of clients as President, Atlantic States Weather. Clients of this firm have included the U.S. Department of Justice, the U.S. Department of Defense, the North Carolina Attorney General's Office, and over 165 law offices and other clients representing both plaintiffs and defendants in legal cases in 30 states, the District of Columbia, Puerto Rico, the United Kingdom, and Greece.



Thomas C. Moore
Certified Consulting Meteorologist
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Holly Springs, North Carolina
April 19, 2023

I. Summary

Public severe weather reports, National Weather Service (NWS) text and graphics products, and community hail reports were inventoried and thoroughly analyzed to determine the potential for severe hail at the Colston Building, located at 10 W. Main St, Ardmore, OK (hereafter referred to as "the Property") on August 16, 2020.

For this report, "severe hail" is defined as hail greater than or equal to 1" in diameter (NWS definition). This is also the hail size required to meet the NWS definition for a severe thunderstorm; the NWS definition for severe thunderstorms also includes winds greater than or equal to 50 kts/58 mph.

The analysis confirms that a severe thunderstorm moved over the Property during the afternoon of August 16, 2020, producing severe hail of 1.25" to 1.75" at the Property.

II. Report Preparation Process

Five sources of meteorological data were analyzed to determine the potential presence of severe hail at the Property on August 16, 2020.

1. Community Collaborative Rain, Hail and Snow Network (CoCoRaHS)

CoCoRaHS is a unique, non-profit, community-based network of volunteers working together to measure and map precipitation (rain, hail, and snow). The CoCoRaHS network uses low-cost measurement tools, stresses training and education, and utilizes an interactive website, in order to provide the highest quality data for natural resource, education and research applications. CoCoRaHS precipitation data can be used to supplement and/or validate other sources of precipitation measurements, such as NWS data and Doppler radar imagery. For this report, the CoCoRaHS hail reports and daily comments database for Carter County, OK for August 16, 2020, were reviewed.

2. Doppler Radar Imagery

NEXRAD or Nexrad (Next-Generation Radar) is a network of 160 high-resolution Doppler weather radars operated by the NWS, the Federal Aviation Agency (FAA), and the U.S. Air Force within the Department of Defense (DOD). Its technical name is WSR-88D (Weather Surveillance Radar, 1988, Doppler). These Doppler radars generate numerous products to help analyze the weather for a specific time and location. In 2013, the NWS completed a dual polarization upgrade (referred to as “dual pol”) to the NEXRAD network that allowed the radars to transmit and receive both horizontal and vertical pulses, greatly increasing the radar’s storm and precipitation identification capabilities. For this report, four products from the Dallas, Ft. Worth, TX NWS Doppler radar site (“KFWS”) and the Oklahoma City, OK NWS Doppler radar site for various times on August 16, 2020, were reviewed. These radars are located approximately 110 miles south, and 81 miles north, of the Property, respectively.

“*Base Reflectivity***”** *(Z)* images are what you see on television or on the Internet. The radar sends out a signal and when it hits precipitation, part of the signal is reflected back to the radar, and the returned energy to the radar expressed in values of decibels (dBZ). For areas of light precipitation, less of the signal is returned, and is indicated on base reflectivity products as the “cool” colored pixels (blue, green). As the precipitation gets heavier, more of the signal is returned to the radar and is shown as increasingly “warm” colored pixels (yellow, orange, red) in the image (higher than 50 dBZ energy return). Base reflectivity products can also assist in identifying storm structure, and location of maximum storm strength. Reflectivities of higher than 55 dBZ can indicate the presence of a severe thunderstorm.

II. Report Preparation Process (Cont)

Base reflectivity products are also a main component of the Doppler radar algorithm known as the Hail Detection Algorithm (HDA), which assesses the potential for hail. For a given storm, the HDA calculates the *Probability of Hail*, the *Probability of Severe Hail (POSH)* (larger than 0.75" in diameter), and the *Maximum Estimated Hail Size (MEHS)* - an estimate of the maximum size of hail that can be expected with a storm. The POSH and MEHS calculations can be displayed graphically as a radar derived product. Note that the POSH severe hail is defined as 0.75" because that was the NWS definition of severe hail at the time the radar algorithm was created. Since that time, the NWS has revised its definition of severe hail to be defined as 1" or larger, but the radar algorithm was not updated to reflect this change.

"Dual Pol" Products

Along with reflectivity, three dual pol products have been found useful in determining severe vs non-severe hail sizes.

"*Correlation Coefficient" (CC)* radar products provide a measure of the consistency of the shapes and sizes of targets within the radar beam, and are shown without units. A higher value shows a higher consistency in the size and shape of radar targets, indicating rain as the predominate type of precipitation, while a lower value indicates larger variability in shapes and sizes, and implies the presence of hail.

"Differential Reflectivity" (ZDR) radar products indicate the logarithm ratio of the horizontally polarized reflectivity to the vertically polarized reflectivity, in units of dBZ. Positive values of ZDR indicate that dominant hydrometeors are larger in the horizontal than in the vertical, and indicate presence of rain drops. Negative values indicate dominant hydrometeors are larger in the vertical than the horizontal, and indicate the presence of hail.

"Specific Differential Phase" (KDP) is a derived product that shows the gradient, or change, in Differential Phase Shift (ΦDP). Differential Phase Shift is a measure of the difference in 2-way attenuation for the horizontal and vertical pulses in a pulse volume; however, values are cumulative along a particular radar radial, which makes it more difficult to interpret. KDP is an easier way to view/interpret the attenuation between horizontal and vertical pulses. Positive KDP values indicate greater phase shift in the horizontal than the vertical.

II. Report Preparation Process (Cont)

The National Oceanic and Atmospheric Administration (NOAA)/NWS Warning and Decision Training Branch, which develops and delivers training on the integrated elements of the severe weather warning process, has developed a suggested severe weather warning methodology, to include assessing hail size (i.e., defining between severe and non-severe hail).

Table 1 shows potential values for the four previous Doppler radar products, and their possible interpretation in terms of hail size:

Dual Pol Product	Dual Pol Values	Hail Interpretation
Reflectivity (Z)	45-59 dBZ	Hail possible
	≥ 60 dBZ	Hail likely
Differential Reflectivity (ZDR)	-0.3 to 1 dB	Dry or large hail
	> 1 dB	Rain; melting hail
Correlation Coefficient (CC)	0.93-0.97	1-2" hail
	0.70-0.90	≥ 2" hail
Specific Differential Phase (KDP)	<1°/km	Mostly dry hail
	>3°/km	Rain and hail mixed; melting hail

Table 1. *Doppler radar dual pol products, values and interpretation for hail type and size. Derived from NOAA/NWS WDTD Suggested Severe Weather Warning Methodology, page 6.*

While using a single radar product from the list above may provide information about potential hail size associated with a thunderstorm, using multiple products will provide a better assessment for potential hail size. Specifically, the values for the four products can be combined into a single matrix/guide, as shown in Table 2:

II. Report Preparation Process (Cont)

Hail Size/Type	Dual Pol Matrix/Signature	
Severe Hail (little or no rain)	Z > 55 dBZ	ZDR < 1 dB
	CC = 0.95-0.97	KDP < 1°/km
Severe Hail (mixed with rain	Z > 55 dBZ	ZDR = 1-2 dB
	CC= 0.93-0.96	KDP > 0.5°/km
Non-Severe Hail (dry)	Z = 45-55 dBZ	ZDR = 0 dB
	CC ≥ 0.98	KDP = 0°/km
Non-Severe Hail (melting)	Z> 55 dBZ	ZDR = 2 dB
	CC = 0.92-0.96	KDP > 4-5°/km
Hail ≥ 2"	Z > 55 dBZ	ZDR ≤ 0 dB
	CC = 0.70-0.90	KDP N/A

Table 2. *Doppler radar dual pol products matrix for hail type and size for hail. Derived from NOAA/NWS WDTD Suggested Severe Weather Warning Methodology, page 11.*

Within this matrix, the Z and CC products are the most reliable products in terms of assessing the presence of hail. ZDR and KDP products can be used to further assess hail potential, after reviewing Z and CC products. In general, the CC, ZDR, and KDP products should be assessed in the same location as the highest reflectivities (Z).

The Doppler radar imagery above was viewed/accessed via two software programs:

1. The National Oceanic and Atmospheric Administration (NOAA) Weather and Climate Toolkit (WCT) is free, platform independent software distributed from NOAA's National Centers for Environmental Information (NCEI). The WCT allows the visualization and data export of weather and climate data, including radar, satellite, and model data.

2. Gibson Ridge "GR2Analyst Version 3" is a commercially available Windows viewer for live and archived NEXRAD Level II data, and is used by NWS offices and consulting meteorologists for weather research and studies. Base reflectivity, base velocity, storm relative velocity, and spectrum width sweeps for all radar tilts are available. In addition, dual polarization data, high resolution derived products (e.g., Echo Tops, MEHS, etc.), cross-sections, and volumetric display are available via GR2Analyst.

II. Report Preparation Process (Cont)

3. National Oceanic and Atmospheric Administration (NOAA)/National Centers for Environmental Information (NCEI) Storm Event Database (SED) and San Angelo, TX, NWS Forecast Office Local Storm Reports (LSRs)

NWS offices across the country gather reports of all types of weather occurrences. Reports meeting severe weather criteria (i.e., hail ≥ 1", winds ≥ 58 mph, and tornadoes) are vetted to ensure accuracy, and then archived in the NCEI SED, where they are available for review. Reports not meeting severe criteria are archived as LSRs by the reporting NWS office, and are available for viewing via the Iowa State University (ISU) "Iowa Environmental Mesonet," which provides access to archived NWS text products, filtered by the issuing NWS center and by date. For this report, severe hail reports from the SED for Carter County, OK, for August 16, 2020, were reviewed. In addition, LSRs from the Norman, OK, NWS Forecast Office ("NWS OUN") for the same date were reviewed.

4. NOAA/NCEI Local Climatological Data (LCD)

Local Climatological Data (LCD) consist of hourly, daily, and monthly summaries for approximately 950 U.S. Automated Surface Observing System (ASOS) stations, as well as observations collected every 20 minutes from around 1,400 U.S. Automated Weather Observing System (AWOS) stations. ASOS and AWOS are government sponsored and maintained observing systems. For this report, the data from Ardmore Downtown Executive Airport, OK ("AHD," hereafter "Ardmore Executive Airport;" located approximately 1.8 miles south of the Property) and the Ardmore Municipal Airport, OK ("ADM," hereafter, "Ardmore Municipal"; located approximately 11 miles northeast of the Property) were reviewed for August 16, 2020. Since the Property is in close proximity to these airports (Figure 1), the observations from these airports can be used in conjunction with other NOAA/NWS data to determine weather conditions at the Property.

II. Report Preparation Process (Cont)

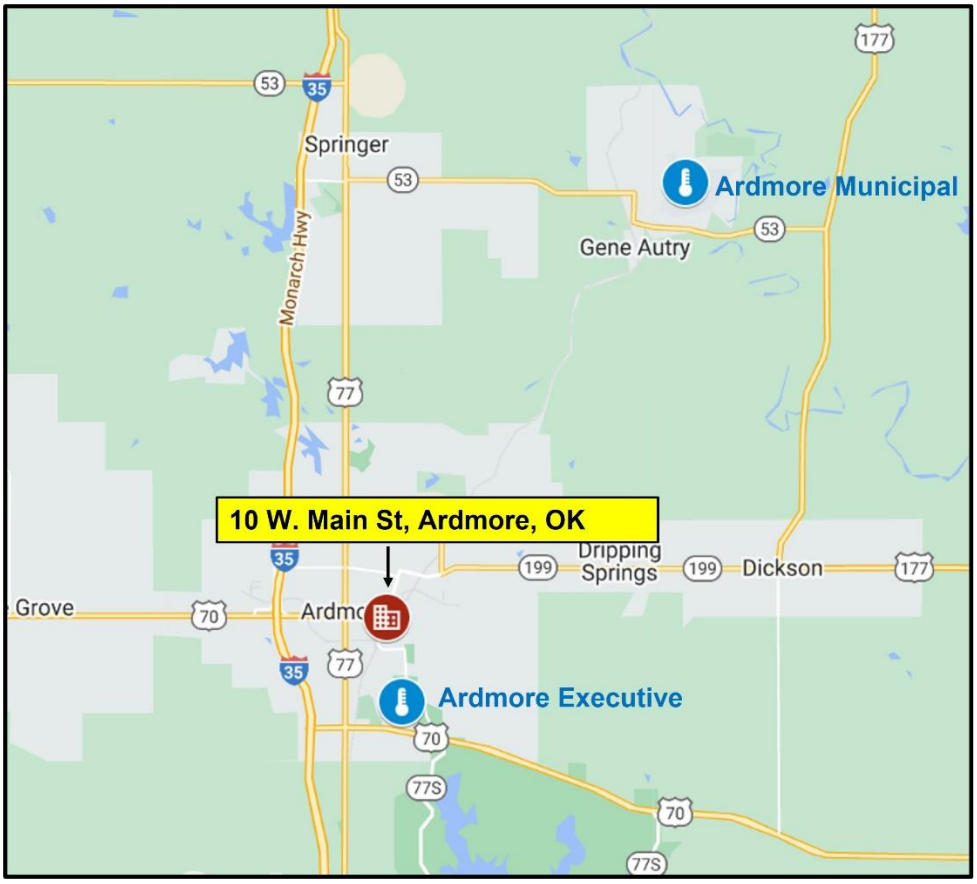

Fig. 1. *Location of LCD airports in relation to the Property*

5. NWS Text Products

For this report, numerous text products from NWS OUN for August 16, 2020, were reviewed. These text products were accessed via the Iowa State University (ISU) "Iowa Environmental Mesonet," which provides access to archived NWS text products, filtered by the issuing NWS center and by date.

Other Files Reviewed:

USBE, Inc. Engineering Evaluation Report - Industrial Models, Inc Roofing Investigation, 1711 Westaire Dr, Gainesville TX (UBSE Project Number: 21434 (07/09/2021))

III. Analysis for Severe Hail at 10 W. Main St, Ardmore, OK (August 16, 2020)

NWS OUN Hazardous Weather Outlook (HWO) issued at 3:34 pm Central Daylight Time (CDT) on this date indicated the possibility of severe thunderstorms through 10:00 pm across most of Oklahoma, noting that the strongest thunderstorms would be capable of producing hail to size of half dollars (1.25") and wind gusts to 60 mph:

```
Hazardous Weather Outlook...UPDATED
National Weather Service Norman OK
334 PM CDT Sun Aug 16 2020

OKZ004>048-050>052-TXZ083>090-172045-
Harper-Woods-Alfalfa-Grant-Kay-Ellis-Woodward-Major-Garfield-
Noble-Roger Mills-Dewey-Custer-Blaine-Kingfisher-Logan-Payne-
Beckham-Washita-Caddo-Canadian-Oklahoma-Lincoln-Grady-McClain-
Cleveland-Pottawatomie-Seminole-Hughes-Harmon-Greer-Kiowa-Jackson-
Tillman-Comanche-Stephens-Garvin-Murray-Pontotoc-Coal-Cotton-
Jefferson-Carter-Johnston-Atoka-Love-Marshall-Bryan-Hardeman-
Foard-Wilbarger-Wichita-Knox-Baylor-Archer-Clay-
334 PM CDT Sun Aug 16 2020

This hazardous weather outlook is for portions of northern...
western...central...and southern Oklahoma...and western north
Texas.

.DAY ONE...Through Tonight...

.Heat...
Heat index values of 105 to 110 are expected in southern Oklahoma
and western north Texas this afternoon.

.Thunderstorms...
There is a marginal risk of severe thunderstorms across most of
Oklahoma and all of north Texas through around 10 PM. In
Oklahoma, the marginal risk of severe storms is southwest of a
line from Medford to Guthrie to Holdenville. The strongest storms
will be capable of producing hail to the size of half dollars and
wind gusts of 60 mph. These thunderstorms will move south and
southeast.
```

During the midafternoon hours, NWS OUN tracked a line of severe thunderstorms moving across south central OK, and at 4:19 am CDT, issued a severe thunderstorm warning for hail up to a quarter size (1") associated with these storms. Ardmore, TX was included in the warned area:

```
BULLETIN - IMMEDIATE BROADCAST REQUESTED
Severe Thunderstorm Warning
National Weather Service Norman OK
```

III. Analysis for Severe Hail at 10 W. Main St, Ardmore, OK (August 16, 2020) (cont)

```
419 PM CDT Sun Aug 16 2020

The National Weather Service in Norman has issued a

* Severe Thunderstorm Warning for...
  Northeastern Jefferson County in southern Oklahoma...
  Northern Love County in southern Oklahoma...
  Southeastern Stephens County in southern Oklahoma...
  Carter County in southern Oklahoma...

* Until 515 PM CDT.

* At 419 PM CDT, severe thunderstorms were located along a line
extending from near Springer to 3 miles southeast of Graham to 5  miles
northwest of Healdton, moving southwest at 15 mph.

  HAZARD...60 mph wind gusts and quarter size hail (1").

  SOURCE...Radar indicated.

  IMPACT...Hail damage to vehicles is expected. Expect wind damage
to roofs, siding, and trees.

* Locations impacted include...Ardmore, Lone Grove, Healdton, Wilson,
Dickson, Ringling, Springer, Gene Autry, Graham, Overbrook, Lake
Murray, Milo and Cornish.
```

At 4:46 pm CDT, NWS OUN issued a new warning for this line of severe thunderstorms, increasing the expected hail size to ping pong ball size (1.5")

```
BULLETIN - IMMEDIATE BROADCAST REQUESTED
Severe Thunderstorm Warning
National Weather Service Norman OK
446 PM CDT Sun Aug 16 2020

The National Weather Service in Norman has issued a
* Severe Thunderstorm Warning for...
  Johnston County in southeastern Oklahoma...
  Northeastern Love County in southern Oklahoma...
  Southeastern Carter County in southern Oklahoma...
  Marshall County in southeastern Oklahoma...
  Southern Murray County in southern Oklahoma...
* Until 615 PM CDT.

* At 446 PM CDT, severe thunderstorms were located along a line
extending from 5 miles west of Mill Creek to near Springer to near Lone
Grove, moving southeast at 15 mph.
```

III. Analysis for Severe Hail at 10 W. Main St, Ardmore, OK (August 16, 2020) (cont)

HAZARD...Ping pong ball size hail (1.5″) and 60 mph wind gusts.

SOURCE...Public.

IMPACT...People and animals outdoors will be injured. Expect hail damage to roofs, siding, windows, and vehicles. Expect wind damage to roofs, siding, and trees.

*** Locations impacted include... Ardmore, Sulphur, Madill, Tishomingo, Davis, Lone Grove, Kingston, Dickson, Mannsville, Springer, Ravia, Mill Creek, Milburn, Dougherty, Gene Autry, Fillmore, Reagan, Turner Falls, Overbrook and Lake Of The Arbuckles.**

Figures 2-3 are radar imagery for one of these severe thunderstorms at the time it passed over the Property (approximately 4:25 pm CDT).

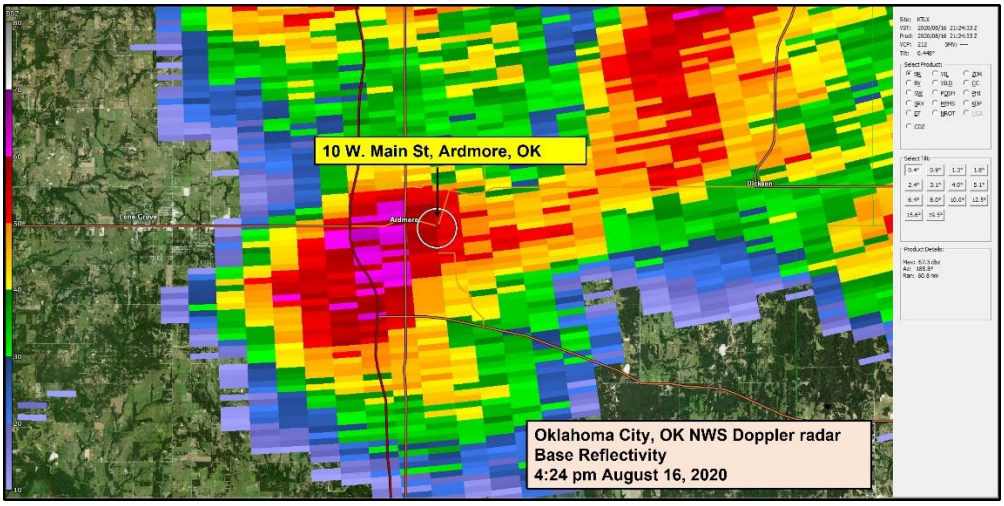

Fig. 2. *KTLX Doppler radar base reflectivity product (4:24 pm CDT, Aug 16, 2020). Location of the Property is shown by red square/white circle.*

Figure 2 shows reflectivities of up to 59 dBZ passing over the Property; reflectivities of this magnitude are associated with severe hail. Figure 3 is a 4 panel image showing the base reflectivity (Z) product compared with dual pol radar products (CC, ZDR, and KDP). Severe hail indicators of 0.90-0.95 CC; 0 to -1 dB ZDR, and 2-3 °/km KDP were identified in the thunderstorm as it passed over the Property.

III. Analysis for Severe Hail at 10 W. Main St, Ardmore, OK (August 16, 2020) (cont)

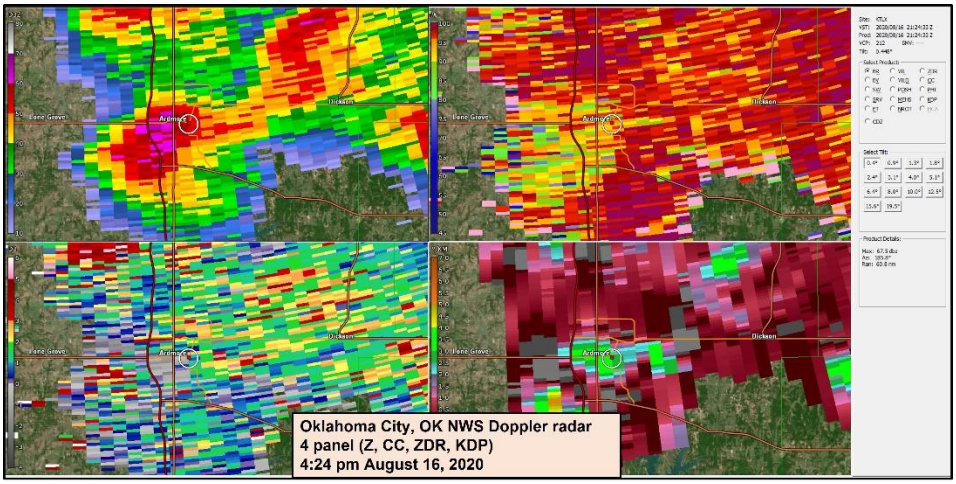

Fig. 3. *KTLX Doppler radar 4 panel image (Z, CC, ZDR, KDP, 4:24 pm CDT, Aug 16, 2020). Location of the Property is shown by red square /white circle.*

At approximately 4:25 pm CDT, NWS OUN received a report of hail ranging from half dollar size (1.25") to golf ball size (1.75") falling in Ardmore, OK. The latitude/longitude for this report places it within 0.7 of a mile west of the Property.

```
PRELIMINARY LOCAL STORM REPORT
NATIONAL WEATHER SERVICE NORMAN OK
443 PM CDT SUN AUG 16 2020

..TIME...    ...EVENT...       ...CITY LOCATION...      ...LAT.LON...
..DATE...    ....MAG....       ..COUNTY LOCATION..ST..  ...SOURCE....
             ..REMARKS..

0425 PM      HAIL              ARDMORE                   34.17N 97.14W
08/16/2020   E1.75 INCH        CARTER OK                 PUBLIC

             HALF DOLLAR TO GOLF BALL SIZE HAIL IN ARDMORE VIA
             FACEBOOK.
```

In summary, a review of NWS text products, NWS Doppler radar imagery, and observed hail reports confirms that a severe thunderstorm moved over the Property during the afternoon of August 16, 2020, producing severe hail of 1.25" to 1.75" as it did so.

IV. Findings and Opinions

- A severe thunderstorm moved over the Property during the afternoon of August 16, 2020.
    - This thunderstorm produced severe hail of 1.25” to 1.75” at the Property.

V. References

CoCoRaHS: Hail reports and daily comments from CoCoRaHS stations in Carter County, OK, for August 16, 2020. Available online at:
https://www.cocorahs.org/ViewData/ListHailReports.aspx
https://www.cocorahs.org/ViewData/ListDailyComments.aspx

FAA Surface Weather Observation Stations (ASOS/AWOS). Available online at
https://www.faa.gov/air_traffic/weather/asos/

Google Earth Pro and Google Maps: Satellite images and Mapping

NOAA/National Centers for Environmental Information, NCEI: Ft Worth/Dallas, TX NWS Doppler radar site (“KFWS”) and Oklahoma City, OK NWS Doppler radar site (“KTLX”) for various times on August 16, 2020. Available online at
http://www.ncdc.noaa.gov/nexradinv/chooseday.jsp?id=kfws
http://www.ncdc.noaa.gov/nexradinv/chooseday.jsp?id=ktlx and
https://s3.amazonaws.com/noaa-nexrad-level2/index.html

NOAA/NCEI: Storm Event Database (SED) results for Carter County, OK for August 16, 2020. Available online at:
https://www.ncdc.noaa.gov/stormevents/choosedates.jsp?statefips=40%2COKLAHOMA

NOAA/NCEI: Local Climatological Data (final) including monthly summary, hourly observations, and hourly precipitation for Ardmore Executive Airport, TX (“AHD”) and Ardmore Municipal Airport, TX (“ADM”) for August 16, 2020. Available online at
https://www.ncdc.noaa.gov/cdo-web/datatools/lcd

Norman, OK NWS Forecast Office (“NWS OUN”): LSRs and NWS text products at various times on August 16, 2020. Available online at
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NWS Jackson, MS: Dual-Pol Applications. Available at
https://www.weather.gov/jan/dualpolupgrade-applications

VI. References (cont)

NWS Warning Decision Training Division: Radar Applications Course (RAC) and Severe Warning Methodology:
https://training.weather.gov/wdtd/courses/rac/outline.php
https://training.weather.gov/wdtd/courses/rac/documentation/rac18-warn-method.pdf

Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM): Federal Meteorological Handbook No. 11 "WSR-88D Meteorological Observations:

- Part C; WSR-88D Products and Algorithms. Available online at *https://www.icams-portal.gov/publications/fmh/FMH11/fmh11partC.pdf*

- Part D; WSR-88D Unit Description and Operational Applications. Available online at *https://www.icams-portal.gov/publications/fmh/FMH11/FMH11D-2006.pdf*

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Curriculum Vitae

Thomas C. "TC" Moore,
Certified Consulting Meteorologist (CCM)
President - Atlantic States Weather, Inc.

Professional Experience

AMS Certified Consulting Meteorologist and Military Veteran with 32+ years of proven ability to provide consulting, forecasting, research, planning, and policy development in the field of meteorology. Possesses a comprehensive background in scientific research and analysis, operational and severe weather forecasting, staff supervision, and project management derived from conducting domestic and global operations. Managed operational budgets, contracts, and proposals valued above $2M. Career supported by military training and a Master of Atmospheric Science degree, with extensive knowledge in:

Meteorological Research and Analysis
Risk Assessment and Disaster Response
Severe Weather Analysis and Forecasting
Forensic Meteorology
Hazardous Weather Assessment
Agriculture Loss Claim Meteorology

Forensic/Consultant Meteorologist, 2019 – Present:

2019 – Present **President, Atlantic States Weather, Inc., Raleigh, NC**
Owner and president of the meteorological consulting firm providing forensic meteorology, environmental analysis, and expert witness services for attorneys, insurance companies, businesses, engineers, architects, government agencies, and private citizens. Provides analyses of impacts of high winds, tornadoes, hail, ice (slip and fall), flooding rains, and dangerous temperatures; specializes in reconstructing hurricane associated winds and storm surge impact at specific locations. Supports agricultural insurance claims arising from meteorological and/or climatological events (Noninsured Crop Disaster Assistance Program (NAP) and Wildfire and Hurricane Indemnity Program (WHIP)). Clients of Atlantic States Weather have included the U.S. Department of Justice, U.S. Department of Defense, the North Carolina Attorney General's Office, the North Carolina Division of Emergency Management, and over 165 law offices and other clients representing both plaintiffs and defendants in legal cases in 30 states, Puerto Rico, the District of Columbia, Canada, the Bahamas, the United Kingdom, Greece, and at sea.

Federal Civil Service Meteorologist (Department of the Air Force), 2011-2019:

2013 – 2019 **Chief, Interagency Weather Integration, Pentagon, Washington D.C**.
Directed development of strategic plans to integrate emerging science and technology for the purpose of improving weather resource planning and programming. Served on multiple interagency multi-discipline working committees and working groups; act as liaison to maintain effective working relationships with federal agencies. Served as US Air Force (USAF) representative to the Secretary of Defense's Climate Change Resiliency Working Group, collaborating with nine agencies on a Policy and Adaptation plan; identified at-risk USAF bases for vulnerability surveys. Teamed with government, academia, and private industry to produce new Engineering Weather Data reports for USAF installations using current climate change models and data.

2011-2013 **Chief, Environmental Science Integration, Pentagon, Washington D.C.**
Functioned as the Operational Science advisor to the USAF Director of Weather. Identified evolving technologies, capabilities, applied scientific methods and meteorological tools consistent with USAF's current

mission and future support capability. Coordinated climatological survey for future global atmospheric cloud conditions to increase understanding of the impacts on USAF Intelligence, Surveillance, and Reconnaissance missions.

Weather Officer (United States Air Force), 1989-2011 (22 Years Active Duty):

2008-2011 **Deputy Chief and Chief, Weather Policy Division, Pentagon, Washington D.C.**
Led staff of 7 to develop policy and training guidance in support of 2,800 personnel across 160 locations worldwide. Led research and publication projects and facilitated workshops. Responsible for development, updating and editing of multiple HQ level plans, instructions and reports. Spearheaded coordination and rewrite of major guidance document for use of meteorological codes at USAF airfields in order to conform with International Civil Aviation Organization requirements. Led working group of weather, maintenance, and flying personnel to address USAF severe weather forecasting and warning dissemination processes. Primary USAF contributor to updates on Joint Meteorological and Oceanographic (METOC) instructions and guidance governing all US military service METOC operations.

2006-2008 **Commander, 337th Recruiting Squadron, Air Force Recruiting Service, Shaw AFB, SC**
Oversaw Recruiting Operations from community engagement and contract development to team management and special event coordination. Communicated effectively in oral and written form to maintain relationships with state, local partners and general public; delivered numerous public presentations within local communities. Implemented and exercised procedures for severe weather/natural disasters to account for safety of 110 personnel and their families living working in 45 offices across North and South Carolina. Unit earned multiple USAF Standard of Excellence awards and was recognized as the "Top USAF Squadron for Enlisted Recruiting Accessions" (#1/28).

2004-2006 **Director of Operations, 28th Operational Weather Squadron, 20th Fighter Wing, Shaw AFB, SC**
Oversaw the delivery of 24-hour weather support for military operations within Iraq, Afghanistan, and across the SE US. Maintained and coordinated on unit responsibilities in multiple military installation emergency response plans. Led all unit training, standardization and

evaluation, and systems administration and communications. Coordinated severe weather response plans and actions with multiple installations/clients. Managed operations and development for 11 directly supervised personnel and 250 other staff members in 2 work centers to deliver weather support and forecasting services to 120 locations across 5,000,000 square miles. Directed the US Central Command (USCENTCOM) Joint Weather Center for a multi-national force in Iraq; oversaw the production of 10,000 area forecasts, 18,000 severe weather warnings, and 43,000 US Army and USAF airfield forecasts.

2001-2004 **Staff Weather Officer, U.S Air Forces in Europe (USAFE), Ramstein AB, Germany**
Programmed and executed $2.1M budget for weather operations, systems and logistics supporting all USAF and US Army (USA) forces and installations in Europe and the UK. Oversaw weather operations and evaluation programs for 25 units/400 weather personnel to include resource protection for 470 DOD facilities/300K people/$300B aircraft. Authored and coordinated contingency weather support plan for all USAF and USA installations in Europe and the UK, to include severe weather response processes and procedures. Managed fielding of new fixed-based automated weather observing systems across Europe. ***Special Duties*:** Weather Briefer to the NATO Regional Air Commander/ staff: provided environmental intelligence for NATO rapid response fighter aircraft. Adjunct member, USAFE Inspector General staff: inspected and evaluated USAFE weather units on preparation and execution of their wartime missions. Awarded USAF Master Meteorologist badge (2004).

1997-2001 **Weather Flight Commander, 4th Fighter Wing (4FW), Seymour Johnson AFB, NC,**
Led 18-person unit providing 24-hr weather support for 100+ fighter/tanker aircraft. Served as lead for environmental information during activation of the 4th Fighter Wing Emergency Operations Center and presented weather briefings to senior leaders. Primary information source for base leadership for severe weather impacting 5.5K people/$3B in assets -- provided accurate hurricane notifications to wing leadership to guarantee the safe evacuation/recovery of all aircraft during four separate tropical storms impacting the installation. Authored and coordinated the installation weather support plan, to include severe weather and hurricane response processes and procedures. Deployed to Balikeshir, Turkey to set up and execute bare base weather support for 4th Fighter Wing operations during Operation Allied Force.

Special Duties: USAF Weather Liaison aboard the US Navy Command Ship *USS Mt Whitney:* supported joint air operations planning and execution during Exercise JTFEX 00-01. Joint Meteorological and Oceanographic Officer, Riyadh, Saudi Arabia: Supported USCENTCOM's "Operation Southern Watch" (Joint Task Force- SW Asia (JTF-SWA):
- led a team of 4 to provide weather support for air operations planning and execution in the JTF-SWA Combined Air Operations Center (CAOC)
- provided daily briefing to the CAOC commander on weather impacting JTF-SWA missions and personnel
- personally briefed critical cloud amount and surface wind "Go/No-Go" forecasts for United Nations U-2 Reconnaissance Missions.

1995-1997 **Chief of Air Quality Meteorology and Chief, Air Quality and Hazardous Waste Branch, Armstrong Laboratory, Brooks AFB, TX**
Oversaw all aspects of air pollution and hazard waste mitigation operations across numerous DoD locations in the US; supervised 14-person team of scientists, engineers, and technicians providing $4M in critical services to DoD agencies on a wide range of environmental issues. Served as the Air Quality Meteorology/ Dispersion Modeling expert on a team of specialists providing a variety of environmental services to DoD installations, including on-site stack sampling, air emissions inventories, and air quality compliance reviews. Awarded USAF Senior Meteorologist badge (1996).

1993-1995 **Graduate Student, Air Force Institute of Technology Civilian Institutions, North Carolina State University, Raleigh, NC**
Competitively selected for graduate degree program in Physical Meteorology, with focus on Atmospheric Chemistry, Planetary Boundary Layer, and Air Quality Meteorology. Designed and equipped mobile research vehicle with 5 highly sensitive measuring instruments and planned, equipped, and executed two research projects involving complex air sampling techniques at ground and elevated levels of the atmosphere; specific research into sources and transport of precursors of ground level ozone published in three peer-reviewed papers.

1990-1993 **Staff Weather Officer, Tanker Airlift Control Center, Military Airlift Command (MAC), Scott AFB, IL**
Led the stand up of a weather support unit for the Tanker Airlift Control Center, a newly organized USAF facility responsible for planning and executing global airlift flights; weather unit earned recognition for "Most Outstanding Specialized Weather Support" in the USAF, 1993
Special duty: Weather Briefer to the Commander-in-Chief, MAC

(CINCMAC): Created and delivered daily morning briefings on weather impacts to tanker and airlift aviation operations across the globe to 4-star General/staff.

1989-1990 **Duty Forecaster, MAC Weather Support Unit, Scott AFB, IL**
Responsible for maintaining situational awareness 24/7 on weather impacting MAC airlift and tanker operations around the globe; coordinated with the MAC Senior Airlift Controller to divert or reroute aircraft to avoid incidents; developed and transmitted Terminal Aerodrome Forecast (TAF) for Rickenbacker ANG, OH. Key contributor to unit being recognized as "USAF Weather Support Unit of the Year", 1991. Certified to operate "Weather Surveillance Radar, 1988-Doppler" (WSR-88D) weather radar.
Special duty: MAC Crisis Action Team Weather Planner: Provided weather support to classified airlift operations for the deployment of 12,000 military members to Panama during Operation Just Cause; successfully forecast severe aircraft icing at multiple USAF and US Army installations, allowing senior leaders to stage aircraft where operations would be least impacted.

Additional Professional Experience

- USAF representative, working group to provide input on US position for the "World Meteorological Organization (WMO) Publication 258 "Guidelines for the Education and Training of Personnel in Meteorology and Operational Hydrology, Vol. 1 Meteorology", Basic Instruction Program - Meteorology (BIP-M) (2015, 2018)
- USAF representative, working group for "Transboundary Waters: Methodologies and Integral Tools to Support Global Water Security Workshop" (2017)
- USAF representative, Strategic Planning Team (SPT) for FAA Research Evolution Planning (REP) Report on Weather Uncertainty (2015); FAA REP Report on Numerical Weather Modeling (2014); and FAA REP Report on Weather Quality Assurance (2014)
- USAF representative, working group to coordinate loan of Oceanographic Reporting Buoys (U.S. ARGO Program) to Peru for El Nino research (2015)
- USAF Directorate of Weather representative, working group; "DoD Concept of Operations for FAA Next Generation Aviation Transportation System (2014)
- USAF Director of Weather representative, working group; "Office of Federal Coordinator of Meteorology Multifunction Phased Array Radar" (2011-2014)

- USAF representative, working group; "The Role of Collaborative Decision Making in Governing the NextGen 4D Weather Data Cube Single Authoritative Source (FAA Joint Planning and Development Office (JPDO) White Paper, 2013)
- USAF representative, working group; "U.S. Navy Arctic Climate Change Capabilities Based Assessment" (2012)
- USAF Directorate of Weather representative, Commerce Spectrum Management Advisory Committee (CSMAC) Working Group 1; "DoD Transition Plan for Commercial Operations in the 1695-1710MHz Band" (2012)

Education:

- Bachelor of Science (Meteorology), North Carolina State University – 1988

  Program composed of a foundation in physical sciences and mathematics followed by specialized courses in meteorology that covered a wide range of topics including weather prediction, severe weather processes, and climate.

- Master of Science (Atmospheric Science) with a Minor in Statistics, North Carolina State University – 1995

  Physical meteorology program focused on atmospheric chemistry, planetary boundary layer, dynamic meteorology, and air quality meteorology, with specific research into sources and transport of precursors of ground level ozone.

- Graduate Certificate (Emergency Management and Disaster Preparation), Trident University – 2008

  16 credit hour program focused on planning for and responding to natural and man-made emergencies and disasters.

Professional Certifications

- American Meteorological Society Certified Consulting Meteorologist (CCM) #748

Publications and Presentations:

- 2022: "The Art and Science of Forensic Meteorology". *Natural Disasters Expo, Miami, FL February 7-8, 2022.*

- 2018: Transboundary Water: Improving Methodologies and Developing Integrated Tools to Support Water: Security Workshop Report and Recommended Path Forward (NASA/TM–2018-219026*). National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland 20771, February, 2018.*
- 2002: "Don't Be Fooled by Mother Nature – Aviation Lightning Strike Hazards", *Air Scoop Magazine* (*U.S. Air Forces in Europe Safety Journal), Summer '02, pg. 11-13.*
- 2001: "Vertical Distribution of Oxides of Nitrogen in the Semi-Urban Planetary Boundary Layer: Mixing Ratios, Sources, and Transport." *Chemosphere, Vol 3 #1.*
- 1997: "National Emission Standards for Hazardous Air Pollutants (NESHAP), Aerospace Manufacturing and Rework Facilities Rule: Operational and economic impacts at U.S. Air Force Air Combat Command (ACC) installations". *Presented at the 90th Annual meeting and exhibition of the Air and Waste Management Association (A&WMA), Toronto (Canada), 8-13 Jun 1997.*
- 1997: Air Quality Test Team Member, Armstrong Laboratory Occupational & Environmental Health (OL/OE) -Technical Report-1997-0118: *"Compliance Sampling of the Type 1 Classified Waste Incinerator, Hickam AFB, HI."*
- 1997: "NESHAP, Aerospace Manufacturing and Rework Facilities Rule: Operational and economic impacts at USAF Space Command (AFSPC) installations". *Presented at the AFSPC Environmental Conf, Peterson AFB, CO.*
- 1996: "Environmental Variables Controlling Nitric Oxide Emissions from Agricultural Soils in the Southeast United States" *Atmospheric Environment, Vol 30 No. 21.*
- 1996: "Seasonal Variations of Nitric Oxide Flux from Agricultural Soils in the Southeast United States" *Tellus, Vol 48B.*
- 1996: Armstrong Laboratory Air Quality Team Member; AL/OE – Technical Report-1996-0080: "*Control Efficiency Determination of Sudden Expansion Incinerator, Kelly AFB, TX."*
- 1995: "Vertical Distribution of Oxides of Nitrogen in the Non-Urban Boundary Layer: Mixing Ratios, Transport and Sources," *Proceedings of the U.S. EPA/A&WMA International Symposium on Measurements of Toxic and Related Air Pollutants, A&WMA Report No. VIP-50, pp. 10-15. 35.*
- 1995: "Measurements, Characterization and Seasonal Variability of Nitric Oxide Fluxes from Agricultural Soils in the Upper Coastal Plain of North Carolina", *Proceedings of the U.S. EPA/A&WMA International Symposium on Measurement of Toxic and Related Air Pollutants, A&WMA Report No. VIP-50, pp. 22-27.*

Professional Society Memberships:

- Air Weather Association (active and retired USAF weather airmen) [1988]
- American Meteorological Society (scientific and professional organization promoting atmospheric, oceanic, and hydrologic sciences) [1989]

  - President, Central North Carolina Chapter AMS, 2015-2019

  - Member, Board of Certified Consulting Meteorologists (BCCM), 2021-present

  - Co-Chair, BCCM - 2023
- National Weather Association (professional association for operational meteorologists) [2012]
- Association of Certified Meteorologists (professional association of certified consulting meteorologists) [2019-present]

  - Chair, Committee on Volunteer Support to Emergency Managers/Disaster Responders

Instructor Positions/Experience:

- Instructor, NC State University Osher Lifelong Learning Institute (OLLI), Raleigh, NC: Prepared and led courses on weather and atmospheric phenomena.
- Instructor, Joint Meteorological and Oceanographic Officer Courses: Prepared and led courses in deployed weather support for USAF and U.S. Army operations.
- Adjunct Faculty, Embry-Riddle Aeronautical University (ERAU), Seymour Johnson AFB: Prepared, led and managed courses in aviation meteorology for USAF enlisted members pursuing undergraduate degree in Airfield Management.
- Adjunct Faculty, USAF School of Aerospace Medicine, Brooks AFB, TX: Prepared and led courses in Air Quality Meteorology and Air Dispersion Modeling

Awards and Recognition:

- USAF Air Combat Command Field Grade Weather Officer of the Year – 2005
- USAF Innovative Development through Employee Awareness (IDEA) Award for Scientific Achievement- 2000
- USAF Company Grade Officer of the Year, 375th Weather Squadron -1993
- Distinguished Graduate, Air Force Reserve Officer Training Corps, North Carolina State University - 1988

Volunteer

American Red Cross Weather Watch Team Lead and Disaster Response Weather Support (1000+ total volunteer hours):

- Leads, motivates, and manages a volunteer team responsible for serving on-call to provide updated severe weather information for Eastern NC Region Red Cross Region (33R16) disaster preparedness, response, and recovery programs – the only program of its kind in the Red Cross.
- Prepare and deliver presentations on severe weather impacts and weather support services to eastern NC Red Cross leadership.
- Assigned as severe weather briefer/consultant to seven Red Cross Disaster Relief Operations (DRO) 2015-2022:
    - 752-16 (SC Floods 2015)
    - 748-16 (NC Hurricanes 2016)
    - 117-17 (Hurricane Matthew, NC)
    - 129-19 (NC Hurricanes 2019)
    - 129-20 (Hurricane Dorian, NC)
    - 505-21 (Hurricane Isaias, NC).
    - 843-2023 (HUR Ian NC 09/22)

National Weather Service (NWS)

- NWS Weather-Ready Nation Ambassador: Partner with NOAA to improve the nation's readiness against severe weather, water, and climate events by motivating individuals and communities to take actions that will prepare them in the event of a weather disaster, and to share their preparedness steps with others.
- Raleigh NWS SKYWARN® Weather Spotter: Assist in keeping local community safe by providing timely and accurate reports of severe weather to the NWS, with a focus on reporting on severe local thunderstorms.

Expert Testimony of Last 4 Years of Thomas C. Moore, CCM (as of Nov 16, 2022)

Trial (T), deposition (D) or hearing (H) for Plaintiff (p) or Defense (d).
Date and location of the event leading to the litigation is also listed.

	Date Event	Location Event	Parties	Case	Retained by	Date of Testimony	Location Testimony
D	07/04/2017	Levelland, TX	Nationwide Agribusiness Insurance Co., as subrogee of Penny Newman Grain Co. vs. Varco Pruden Buildings, Inc, a division of BlueScope Buildings North America, Inc	US District Court, Northern District of Texas Lubbock Division. 5:19-CV-00083-M	Ms. Elizabeth E. Tobin (p) Shook, Hardy, & Bacon Kansas City, MO	08/12/2020	Raleigh, NC (via Zoom)
D	08/25/2017-8/29/2017	Houston, TX	Texas Friends Chabad-Lubavitch, Inc. vs. Nova Casualty Company	US District Court, Southern District of Texas Houston Division. Civil Action No. 4:20-cv-00388	Ms. Peri Alkas (d), Phelps Dunbar, LLP; Houston, TX	12/14/2020	Raleigh, NC (via Zoom)
H	May-June 2017	Jackson County, FL	Trenton A Childs vs. Farm Service Agency	US Department of Agriculture Office of the Secretary National Appeals Division Case No. 2021S000053	Mr. Charles F. Woodhouse (p) Woodhouse Shanahan PA Attorneys at Law 800 Connecticut Ave. NW - Suite 300 Washington, DC 20006	03/18/2021	Raleigh, NC (Via telephone call)
H	August-November 2016	Houston County, FL	Brittany Daniels vs. Farm Service Agency	US Department of Agriculture Office of the Secretary National Appeals Division Case No. 2021S000067 2016 NAP PP02 Hybrid Tomatoes	Mr. Charles F. Woodhouse (p) Woodhouse Shanahan PA Attorneys at Law 800 Connecticut Ave. NW - Suite 300 Washington, DC 20006	03/31/2021	Raleigh, NC (Via telephone call)

Expert Testimony of Last 4 Years of Thomas C. Moore, CCM

Trial (T), deposition (D) or hearing (H) for Plaintiff (p) or Defense (d).
Date and location of the event leading to the litigation is also listed.

	Date Event	Location Event	Parties	Case	Retained by	Date of Testimony	Location Testimony
D	10/8/2016-10/9/2016	Smithfield, NC	Atlantic Resources, Inc., and Barefoot Property Group, LLC, Plaintiff, v. CSX Transportation, Inc., Defendant.	US District Court, Eastern District of North Carolina Western Division Case No.: 5:19-CV-00511-FL	Mr. Andrew Spradlin (d), Millberg Gordon Stewart PLLC. 1101 Haynes St #104, Raleigh, NC 27604	05/27/2021	Law offices of Millberg Gordon Stewart PLLC. Raleigh, NC
D	08/25/2017-08/26/2017	Nueces County, TX	Nueces County, TX vs CERTAIN UNDERWRITERS AT LLOYD'S LONDON SUBSCRIBING TO POLICY NO. AMR-37950-03; INDIAN HARBOR INSURANCE CO.; QBE SPECIALTY INSURANCE CO.; STEADFAST INSURANCE CO.; GENERAL SECURITY INDEMNITY CO. OF ARIZONA; UNITED SPECIALTY INSURANCE CO.; PRINCETON EXCESS AND SURPLUS LINES INSURANCE CO.; HDI GLOBAL SPECIALTY SE FORMERLY KNOWN AS INTERNATIONAL INSURANCE CO. OF HANNOVER SE; OLD REPUBLIC UNION INSURANCE CO.; ROCKHILL INSURANCE COMPANY; AND CERTAIN UNDERWRITERS AT LLOYD'S LONDON SUBSCRIBING TO POLICY NO. LWH000850; AND AMRISC, LLC	Arbitration	Ms. Paige Jones (d); Phelps Dunbar LLP: 115 Grand Ave, Suite 222 Southlake, TX	12/29/2021	Raleigh, NC (via Zoom)
H	03/01/2017-06/20/2017	Jackson County, FL	Donna Moore vs. Farm Service Agency	US Department of Agriculture Office of the Secretary National Appeals Division Case No. 2021S000302 2017 European Eggplant PP01	Mr. William C. Shanahan (p). Woodhouse Shanahan PA Attorneys at Law 800 Connecticut Ave. NW - Suite 300 Washington, DC 20006	02/16/2022	Raleigh, NC (Via telephone call)

Expert Testimony of Last 4 Years of Thomas C. Moore, CCM

Trial (T), deposition (D) or hearing (H) for Plaintiff (p) or Defense (d).
Date and location of the event leading to the litigation is also listed.

	Date Event	Location Event	Parties	Case	Retained by	Date of Testimony	Location Testimony
H	August-September 2016	Jackson County, FL	Jeffery Shelley vs. Farm Service Agency	US Department of Agriculture Office of the Secretary National Appeals Division Case No. 2022S00014 2016 PP02 COM Cucumbers	Mr. Charles F. Woodhouse (p) Woodhouse Shanahan PA Attorneys at Law 800 Connecticut Ave. NW - Suite 300 Washington, DC 20006	05/25/2022	Raleigh, NC (Via telephone call)
D	08/25/2017-8/29/2017	Houston, TX	5556 Gasmer Management LLC (AD HOC) vs. Certain Underwriters at Lloyd's, London, et al	Arbitration	Doug Steinke, Kennedys CMK LLP (d) 120 Mountain View Blvd, Basking Ridge, NJ 07920	06/23/2022	Holly Springs, NC (via Zoom)
H	Sep 11-12, 2017	Jackson County, FL	Trenton A Childs vs. Farm Service Agency	US Department of Agriculture Office of the Secretary National Appeals Division Case No. 2022S000122	Mr. Charles F. Woodhouse (p) Woodhouse Shanahan PA Attorneys at Law 800 Connecticut Ave. NW - Suite 300 Washington, DC 20006	08/31/2022	Southport, NC (via telephone)
D	Aug 13, 2019	Hays, KS	Brotherhood Mutual Ins Co v Bluescope Construction Inc et al	23rd Judicial District of Kansas, District Court of Ellis County, Kansas Case No.: 2021-CV-000027	Mr Brandon Gutshall (d) Shook, Hardy and Bacon 2555 Grand Blvd Kansas City, MO 64108	11/16/2022	Holly Springs, NC (via Zoom Mtg)

				Case No.: 2021-CV-000027			

Publications of Last 10 Years of Thomas C. Moore, CCM

2018: Transboundary Water: Improving Methodologies and Developing Integrated Tools to Support Water: Security Workshop Report and Recommended Path Forward (NASA/TM–2018-219026). National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland 20771, February, 2018.